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RESEARCH ARTICLE

ANALYSIS OF PLANE CRASH IN NIGERIA AND LESSONS LEARNED FROM SPECIFIC DISASTER: DANA AIR 0992, 5N-RAM CRASH

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Abstract

Modern society continues to depend heavily on the wealth and services generated by highly automated and mechanised systems. Therefore, physical assets, including manual and automated systems, must be directed and safeguarded. When these assets fail, life, property, credibility, and trust are typically lost. In the face of rapidly changing technology and maintenance philosophies, one way to avoid failures and catastrophes is to learn from past failures and implement the lessons or recommendations derived from such analyses and reports. Nigeria, like other nations, has experienced disasters caused by asset failures in businesses, factories, and residences.Consequently, the purpose of this article is to raise public awareness and alarm regarding the repercussions of the Nigerian aviation industry's failure to learn from past failures and disasters. As a case study, it employs a documented Dana Air aircraft accident report. In addition, it employs Fault Tree Analysis (FTA), a deductive failure technique, and Reliability Block Diagram (RBD) to gain a deeper understanding of the aircraft accident and its root causes. As a result, a feedback loop is established for the development of additional ideas and actions to prevent future disasters in Nigeria.

Introduction:-

In Nigeria, the Accident Investigation Bureau (AIB) is usually notified officially of any incident and may not be provided with complete information regarding aircraft accidents, hence, resulting in insufficient accident records. In some cases, AIB is notified about aircraft incidents weeks after occurrence. A typical example is the AIB SEA/2019/11/19/F, Cessna 172 5N-APE incident operated by Skypower Express Airways (SEA) Nigeria Limited which departed NnamdiAzikiwe International Airport (DNAA) Abuja for Bida, Niger State. According to (AIB SEA/2019/11/19/F), the incident occurred on 19/11/2019 while the official report of the incident was made on 02/12/2019 - "AIB was notified of this incident by the operator Skypower Express Airway (SEA) on 02/12/2019". This is a clear negation of the essence of learning from failures because a lot of facts must have been cocooned and or refabricated from what would have been gotten from onsite and eye witness reports. In some cases, there are contradicting reports between the Aviation Ministry and the National Transport Safety Board (NTSB) report on same air crash incident. According to (Vanguardngr.com of June 10, 2012), Sunday Vanguard newspaper was informed "It became a bit difficult to release two reports of same air disaster with different conclusions" In this regard, (Adebiyi., 2008) asserts that inconsistencies arise when collecting accident data in Nigeria because official gazettes on accidents are difficult to access. On January 30, 2002, two severe incidents involving two B747-200 series Kabo Aircraft with registration 5N-EEE occurred. The aircraft was about to take off from King Abdul Aziz

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International airport in Jeddah when one of its tyres blew (AIB, 2002a), causing severe damage. On February 5, 2002, as 5N-PPP approached Maiduguri International Airport, another incident report (AIB, 2002b) was filed; the cause was attributed to previously unreported severe damage. This time, the aircraft was irreparably damaged due to a disregard for the adage “a stitch in time saves nine” (O’Hare et al., 1994). (Shappell and Weigmann., 1996) and (Yacavone., 1993) contend that 50 to 85 percent of aviation accidents are caused by human error. However, according to (Heinrich et al., 1980), human error is not the only cause of aviation accidents worldwide, as human capability is comprised of a plethora of complex interactions between multiple factors in addition to “the inextricable bond between individuals, their tools and machines, and their general work environment” (Heinrich et al., 1980, P,51). Succinctly put, the blending; of the increasing dynamics of the aircraft’s physical layout, the task of manoeuvring the aircraft, verbal transmission relationship with the Air Traffic Control (ATC) and constant monitoring of the variable weather conditions, multiply the chances for unexpected events which oftentimes lead to a plane crash.

Contributions/Reports on Nigeria Plane Crash

In contrast to accident reports from developed nations, there is a dearth of literature on aircraft accidents in Nigeria, except for reports from the Accident Investigation Bureau (AIB). In these nations, researchers from universities, organisations, and scientific bodies analyze and process accident investigations reports in such a way that societal awareness of the reports becomes contagious, thereby reinforcing the desired lessons for learning from mistakes. According to (Dayyubu and Danraka., 2014) an empirical analysis of data from 1983 to 2003 indicates that commercial aviation is responsible for over fifty percent of all accidents in Nigeria. In the end, the process of achieving every commercial airline’s goal of having safe and on-time flight operations depends more on her employees, who must carry out functions such as aircraft servicing, refueling, crew manning, passenger/luggage loading, and routine maintenance. These employees implement the organisational philosophy, guidelines for operational actions, and standard procedures. When an airline’s management pursues profit-generating strategies, such as on-time departure at all costs, at the expense of safety, the airline fails. Such a circumstance results in a cascade of unsafe practices among the flight crew and the rest of the airline’s employees. (Morris and Moore., 2000) state that “clearly, failures enable the status quo to change”. Failures challenge the status quo, clichés, and outdated presumptions. They require decision-makers to consider what went wrong, why, and how (Morris and Moore., 2000). Therefore, detailed investigation, analysis, report and publication of failures and catastrophes provide lessons which if learned, prevent the occurrence of future incidents. For these reasons, High Reliability Organisations (HROs) have continued to exercise caution in all aspects of their operations to enhance disaster prevention. HROs such as the military, nuclear power, airline/space shuttle, healthcare, food retail and information technology are cognizant of the fact that minor individual and organisationalbehaviours lead to a variety of failures and catastrophes. Undeniably, Nigerian Aviation Industry is faced with a myriad of challenges which contribute to plane crashes during flight descends at the airports. In one of the customer survey reports (Phillips., 2015) asserts; “Many airports in Nigeria are in a state of complete disrepair, lacking basic infrastructure such as adequate runway capacities and terminal facilities are lacking at major airports in the country.”According to (Feggetter., 2007), “In some cases, human error is a factor in as high as 70 percent of aircraft accidents.” (Adebiyi., 2008) contends that human causal factor resulting from unsafe acts by airline operators exceeded 70 percent in 2005,the year with the highest number of fatal plane crashes in Nigeria (9). Wind shear, which is a change in wind speed and direction, causing shearing or tearing effect has remained one of the greatest challenges to pilots and the airline industry. According to (Justin Hayward., 2021), wind shear caused the Delta Air Lines crash of August 2, 1985 with fatalities of 137 involving 8 flight crew, 134 passengers and 1 Toyota car driver on ground.

DANA/2012/06/03/F Crash

At approximately 15:45:00 hours on June 3, 2012, a domestic scheduled flight owned and operated by Dana Airlines (Nigeria) Limited as flight 0992 (DANACO 0992) crashed into a densely populated area of Iju-Ishaga, a suburb of Lagos, (according to AIB DANA/2012/06/03/F) due to the loss of No. 1 engine power seventeen minutes into the flight and No. 2 engine power during the final approach to the destination airport, Murtala Muhammed Airport Lagos, Nigeria.

All 153 passengers and six crew members aboard the aircraft were fatally injured. In addition, six individuals on the ground lost their lives.

Figure 1: The Aircraft DANACO 0992 before the crash; culled from Aircraft Accident Report DANA/2012/06/03/F

The aircraft flight from Abuja (ABV) to Lagos (LOS) was primarily destroyed by the fire that engulfed it immediately after the crash impact. It was the fourth flight segment of the day, which consisted of two roundtrips between LOS and ABV. DANACO 0992 was on final approach to runway 18R when the crew announced "Mayday, Mayday, Dual Engine Failure – Negative Throttle Response."

Spiral to Disaster

After reporting fuel endurance of 3 hours, 30 minutes, the aircraft took off from ABV at 14:58:00 hours. The crew contacted the Lagos Area control center at 15:18 UTC and reported an estimated arrival time of 15:45 UTC at an altitude of 26,000 feet. The Cockpit Voice Recorder (CVR) started recording at 15:13:44 and retained 30 minutes and 53 seconds of the flight. The recorded voices of the captain and First Officer (F/O) revealed that they were conversing about an abnormal correlation between the throttle setting and an engine power indication. However, they were unaware that the abnormal condition would affect the flight's continuation, and as a result, they never expressed concern. The flight crew continued to monitor the condition and grew increasingly agitated as the flight transitioned from cruise altitude to initial descent, passing subsequent descent altitudes of 18,000 feet and 7,700 feet at 15:30:00 and 15:40:00 hours, respectively. According to the CVR transcript, at 15:27:30 hours, the F/O advised the captain to use runway 18R for landing, and the request was made at 15:31:49 hours; the decision height was subsequently adjusted to correspond with runway 18R. At 15:31:21, the crew confirmed there was no throttle response on the left engine; consequently, the captain assumed Pilot Flying (PF) duties at 15:31:27. However, the flight continued towards the LOS without a distress message being transmitted. At 15:32:05, the crew observed that the No. 1 engine of the aircraft was no longer producing thrust.

Between 15:37:00 and 15:41:00, the flight crew performed pre-landing tasks including deployment of the slats, extension of the flaps, and deployment of the landing gear. At 15:41:46 hours, the F/O inquired, "Are both engines starting?" The captain responded, "No," at 15:41:48 hours. The flight crew later discussed and agreed to declare an emergency. At 15:42:10, DANACO 0992 transmitted an emergency distress signal indicating "dual engine failure, negative response from throttle." At 15:43:27, the captain informed the first officer, "we have just lost everything; we have lost a single engine, and I have lost both engines." During the subsequent 25 seconds until the end of the CVR recording, the flight crew attempted to recover engine power without using any checklist. Approximately 5.8 miles north of the line of sight, the aircraft crashed into a densely populated residential area. According to

(DANA/2012/06/03/F**),** during the impact sequence of the crash, the aircraft collided with an unfinished building, two trees, and three other buildings. Figure 2: shows the top view of the aircraft's number one turbine engine after the crash impact at the crash site.

Figure 2: Top View of Engine 1; culled from DANA/2012/06/03/F report

Logic and Technical Cause of the Disaster

Equipment failures or malfunctions continue to be the leading cause of technical aircraft failures. After reviewing the comprehensive post-accident report of the Accident Investigation Bureau (AIB) on DANA 0992, (DANA/2012/06/03/F)the following factors have been identified as the technical cause of the disaster:

1. Design flaws in the primary and secondary fuel manifold assemblies of the aircraft were the primary technical cause of the accident. Both engines' primary and secondary fuel manifold assemblies were fractured, cracked, bent, twisted, or pinched, resulting in fuel leaks, fuel discharge to the bypass duct, loss of engine thrust, and obviously, failure of the engine to respond to throttle movement.
2. Analysis of post-accident test samples of the aircraft's aviation fuel revealed that it was sourced from two different refinery batches with differing amounts of micro impurity particulates, which must have affected fuel flow in conduits and combustion chemistry.
3. The final aspect of the technical failure was the flight crew's inability to recover engine power. Components of the direct causes include the flight crew's failure to use the checklist, lack of situational awareness or poor airmanship, and failure to land at the nearest suitable airport. Figure 3, shows the right hand side of the aircraft's turbine engine on a pallet at the crash site.

Figure 3: Right Hand Side of Engine 2, culled from DANA/2012/06/03/F report

Contributing Factors

(Labib and Read., 2015) highlighted the importance of categorizing causal factors when analyzing failures as direct cause or contributing factors, particularly for natural disasters. Failures in multidisciplinary environments, such as the aviation industry, which includes operations, maintenance, air traffic control, meteorology, airport services, and firefighting, are crucial. Analysts, engineers, safety and emergency organisations, and responders concentrate on disaster's direct causes. They disregard indirect causes that remain concealed and are poised to become catastrophes. Therefore, when allocating human or financial resources, all contributing events to a disaster must be identified, analyzed, reported, and accounted for.

The DANA 0992 crash resulted from:

1. Noncompliance with the 2003 Service Bulletin SB6452 issued by the aircraft manufacturer. The manufacturer of the aircraft issued a safety alert regarding the secondary fuel manifold assembly of the engine. The product improvement instruction instructed DANA management to install a new secondary fuel manifold assembly because it contains a tube made of new engineering materials with twice the fatigue life of the previous tube material. The engines' disassembly revealed that the No. 1 engine, which was overhauled in the United States in August 2011, did not comply with the Service Bulletin SB6452 safety alert. Both engines' primary and secondary fuel manifold assemblies were fractured, cracked, bent, twisted, or pinched, resulting in fuel leaks, fuel discharge to bypass duct, loss of engine thrust, and obviously, failure of engine responding to throttle movement.
2. The Quality Control (QC) department was not involved in the flight crew hiring process. Numerous inadequacies unearthed by background checks were disproven.
3. DANA management disregarded the report on a similar model engine aircraft in their operation with registration number MD 80, 5N-SAI that had a similar incident in October 2013 and was returned six months after being overhauled due to the engine not responding to throttle movement.
4. The management was insensitive to the numerous negative comments made about the captain. The captain's operating license, which had been revalidated and issued by the Nigeria Civil Aviation Authority (NCAA), was stamped but not signed by any NCAA official. In addition, the captain did not sign the majority of the recommendation letters he submitted. Regarding Standard Operating Procedures (SOP) pertaining to Transition altitudes and levels during descending flights, the captain received additional negative feedback. The United States Federal Aviation Administration (FAA) suspended the captain in 2009 for misdemeanours relating to a hard landing and the retrofitting of panels that were neither recorded nor reported in the aircraft's logbook.
5. The combustion chemistry of the fuel in the turbine's combustion cans would have been affected if a different batch of aviation fuel had been used. On 28/01/2013 (AIB DANA/2012/06/03/F Appendix G), "Following a recent incident involving an air return for an engine failing to respond to throttle movement, the engine was removed for shop investigation after inspection and troubleshooting revealed unburned fuel escaping in the duct section of the engine during ground run." This report clearly demonstrates incomplete combustion, which can be attributed to the use of aviation fuel containing particulates.
6. Imbalance during installation between No. 1 and No. 2 Engine Cycles and operating hours: The technical aspect of the AIB investigation report revealed differences in the operating hours and cycles of the aircraft's twin engines as follows: - Engine No.1 has been flown for a total time of 54318:29 hours and 30,928 cycles while No.2 has flown for a total of 26021:46 hours and 26,021 cycles. One could therefore argue that the variance in these parameters, when distributed across the various engine components, would have contributed to age-related component deterioration.
7. Flaws in the structural design of the primary/secondary fuel manifold: Although this is one of the technical causes of the accident, it is considered a contributing factor because the aircraft model had been in service for years and the operator had received a service bulletin.
8. Failure to recall similar aircraft with faulty secondary manifold assemblies: The inability of the manufacturer of the DANA 0992 aircraft engine to recall all engine models with faulty secondary manifold assemblies contributed to the plane crash. According to (Kageyama, 2010), Toyota recalled 90,000 Lexus and Crown automobiles in Japan due to a quality issue involving safety. Valve springs are a crucial engine component whose failure could cause the vehicle to stall on the road. Also most recently, Agence France-Presse (2022) reported, "Tesla recalls more than 40,000 vehicles due to an issue with the power steering system that was remotely fixed." One would have anticipated that the manufacturer of the aircraft engine would have handled the secondary fuel manifold fault report in the same manner as Toyota and Tesla.
9. The inaccessibility of the crash site due to poor road network and inadequate crowd control hindered the National Emergency Management Agency's (NEMA) emergency response efforts. Perhaps some of the victims who were still

breathing and transported to the hospital after the impact would have survived. Figure 4, shows the gory site of the aircraft's wreckage at the crash venue.

Figure 4: Wreckage site of the Two Engines culled from DANA/2012/06/03/F report

Method of Case Study Analysis

Fault Tree Analysis and Reliability Block Diagram

Figure 5 depicts the Fault Tree Analysis (FTA) of the plane crash, in which the direct cause and contributing causes have been identified. Figure 6 shows the resulting Reliability Block Diagram (RBD). The primary actor in the direct cause is technical failure. The fact that the loss of engine No. 1, the loss of engine No. 2, and the failure of the engine power recovery system are all connected to an AND-gate demonstrates that their concurrent failures led to the failure of the system, or the crash of the aircraft.

The second factor in the direct cause was the flight crew's error, as evidenced by their failure to use the checklist, lack of situational awareness, poor airmanship, and failure to land at the nearest appropriate airport. The contributing factors include OR-gate remarking errors from DANA management, the operator, and the aircraft manufacturer. The operator conducted her flight operations under risk normalization through unsafe acts, including noncompliance with Service Bulletin SB6452, which is a safety alert, non-involvement of the QC department in the pilot hiring process and the use of a different batch of aviation fuel from a different refinery during the flight. These unsafe acts are linked sequentially in the RBD, demonstrating their vulnerability to the Dana airline management and the entire system. More focus and resources should be devoted to this series events, as the failure of any one of them could result in the loss of the entire aircraft system. In addition, the operator was insensitive to the deluge of negative comments made about the captain during; background checks, test flights, and in flights and recall records for a similar engine fault. The second component of the contributing factors is the fault of the aircraft manufacturer. An OR-gate is connected to the cause events 12, 13, and 14, which are defects in the structural design of the primary/secondary fuel manifold, imbalance in work rate between No.1 and No.2 engines at installation relative to their operating hours/cycles, and failure to recall all aircrafts operating with the faulty secondary manifold assemblies. This relationship demonstrates that the failure of any one of them could have contributed to the system failure that resulted in the airplane crash. The RBD sheds more light on the relationship between the plane crash's direct and contributing causes.

However, the system's vulnerability is made more glaring by the arrangement of the blocks which constitute the events of the contributing causes.

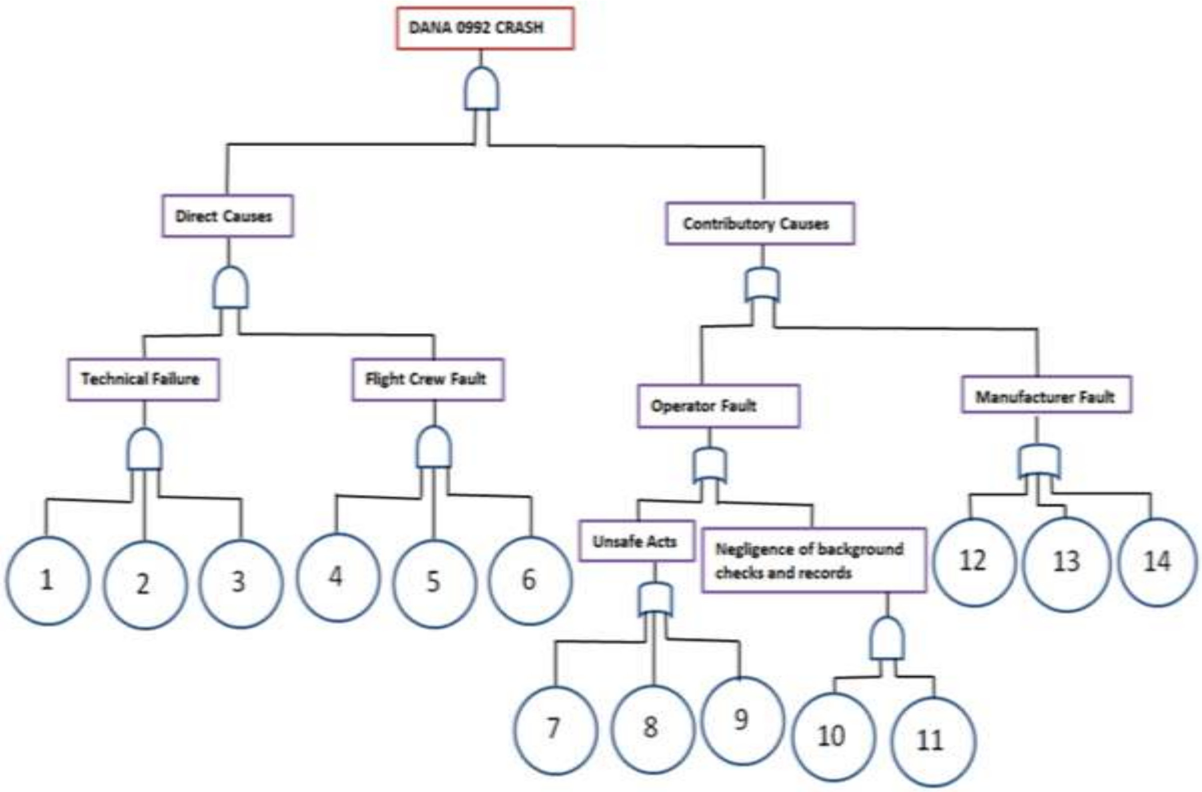

Figure 5: Fault Tree Analysis of DANA 0992 Air Crash

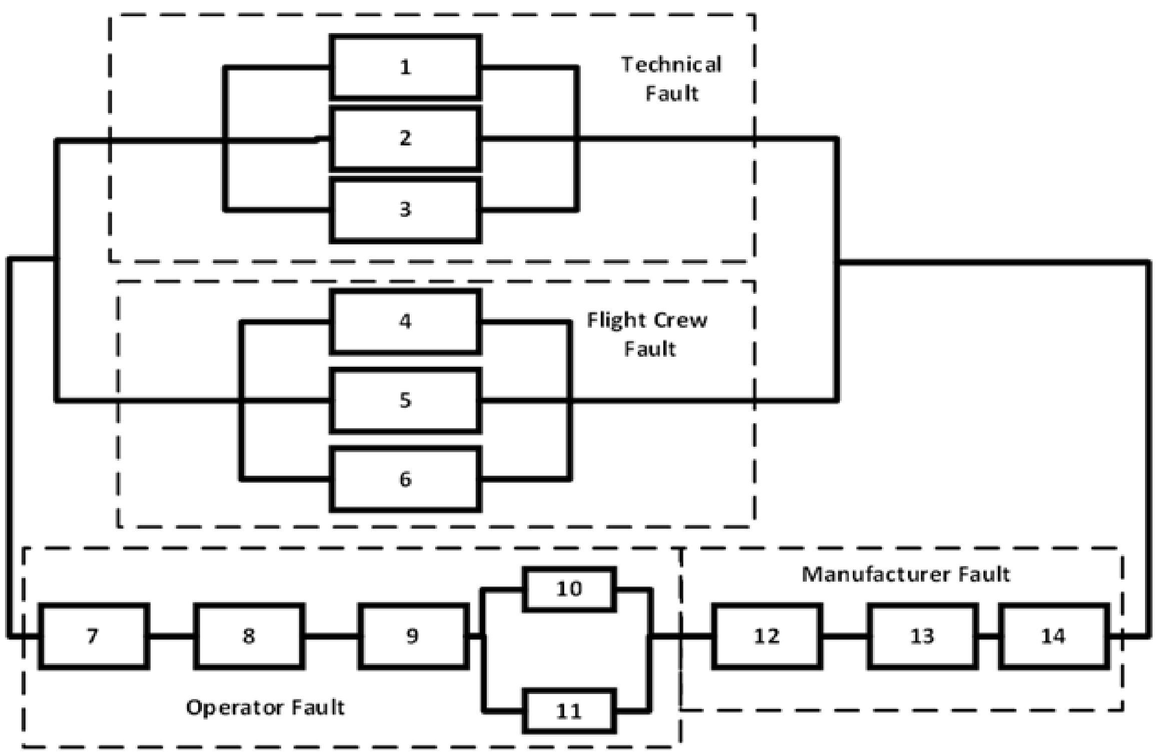

Figure 6: Reliability Block Diagram (RBD) of DANA 0992 Crash

Table 1: FTA and RBD Description

1.	Loss of Engine No. 1
2.	Loss of Engine No. 2
3.	Failure of Engine Power Recovery System
4.	Omission of Use of Checklist
5.	Lack of Situational Awareness and Poor Airmanship
6.	Not Landing at Nearest Suitable Airport
7.	Non-Compliance to SB6452
8.	Non-Involvement of QC during Hiring of the Pilot
9.	Use of Different Refinery batch Aviation Fuel
10.	Insensitive to Poor Remarks on Captain's Background Check Records
11.	Oblivious of Previous Flight Recall on similar Engine Fault Records
12.	Flaws in Structural Design of Primary/Secondary Fuel Manifold
13.	Imbalance at Installation, between No. 1 & No. 2 Engine Operating Hours and Cycles
14.	Failure to recall all Similar Aircrafts operating with faulted Secondary Manifold Assemblies

The minimal cut set, the smallest group of fault initiators whose failure causes system failure, can be deduced from the events 7, 8, 9, (10&11), 12, 13 and 14. All airline operators should not ignore or violate the DANA 0992 plane crash's unsafe acts, negligence of background checks/records, and manufacturer's faults. The FTA captured failure probabilities and logical causative factors, while the RBD revealed system vulnerabilities. These two reliability techniques have improved understanding of the air crash.

(Labib and Read.,2013) argue that feedback should be routed to the design of the current procedure, the development of advanced failure analysis techniques, and the generation of inter-disciplinary generic lessons. Existing airline management procedural design for DANA 0992 relates to their organisational procedures. Routines connect the thoughts, actions, and outcomes of employees. Ideas are generated by actions. These elements will generate change for Dana Airlines and other Nigerian airlines that adopt them.

Advancing Proposals and Inclusive Lessons

Training

The training of aircraft maintenance personnel is recommended as an element of continuous improvement. This can be accomplished by integrating the company's aircraft maintenance employees with those of the Original Equipment Manufacturers (OEMs) during the period of the aircraft's warranty scripts and Contract Service Agreement (CSA). Taking this approach will expose and expand the maintenance scopes of technicians to many inexplicable hands-on techniques hidden in the OEMs team's brains and gloves.

Pilots should receive training on the principles of operations and functions of all the aircraft's technical features. The flight crew on Lion Air Flight 610 of 2018, were unaware of the existence of the Manoeuvring Characteristics Augmentation System (MCAS) and had no postscript information for reference in the manual. According to the accident report by (Oren Liebermann., CNN, 2019) crash reason, “The crashes triggered a redesign of Boeing’s Manoeuvring Characteristics Augmentation System (MCAS) software, including updates to operation manuals and crew training”

Investigators of aircraft accidents should be trained to comprehend human factor elements and how to integrate modern analytical techniques into their services. Therefore, it is essential to strengthen the human factors components of aircraft accident investigations. This method will result in the aviation industry's applicable accident prevention measures and procedures.

Technology Advancement

Incorporating cutting-edge technology into the design and production of aircraft systems is an additional means of advancement. This is supported by the case of Service Bulletin SB6452 of 2003, in which the manufacturer issued instructions for retrofitting a more durable engineering material for the secondary manifold assemblies of a series of aircrafts that have been sold and flown for tens of thousands of hours in various regions of the world. A comprehensive lesson requires a comprehensive analysis of the aircrafts' engineering materials that incorporates global geographical conditions and variables into their design and production. Considering the emergence of new technology in the fields of control and power electronic engineering systems, this is of particular importance. We must agitate and challenge our reasoning on how to increase the dependability and availability of aircraft mobility in the Nigerian and international aviation industries. This will prevent component failures in various zones where the product is used.

Enhancement of Health Management Policies for Aircraft

Boeing claims that Airplane Health management provides a centralized source of information from which airlines can make maintenance decisions on their fleet and identify specific aircraft trends to support her maintenance programs. According to (John B. Maggiore., Boeing.com)it utilizes real-time aero plane data to provide enhanced fault forwarding, troubleshooting, and historical fix information to reduce schedule interruptions and enhance maintenance operational efficiency. Airline operators should incorporate this policy in their maintenance strategy.

Environment and Utilities

Airports in Nigeria should have functional lighting to mitigate visibility, thunderstorm, rainfall, and low cloud issues. At airports, specifically on runways and in Air Traffic Control offices, there should be an uninterrupted supply of electricity. Constant electricity will improve visibility and aid flight crews in maintaining the right decision altitude and preventing heavy landings. Nonetheless, if learning from failures is to be beneficial, deterioration, an important element in the transient path of failure, must be adequately considered when analyzing failures.

Conclusion:-

Due to the random ageing and subsequent failures of the various components that make up equipment's system assembly, it is necessary to guide the safety of the assets' integrity. When implemented, the lessons learned from failure become motivational additions to disaster prevention technologies and techniques. Near-misses and catastrophes in the airline industry must be reported and reemphasized in the public sphere to reduce global repetition. As a means of reducing disasters in general, the analysis also considered the significance of effectively addressing the human causes of aviation accidents. As a result, the FTA and RBD of the DANA 0992 crash were developed to facilitate comprehension of the relationship between all the disaster's contributing factors. There should be an all-inclusive framework for human error from which new investigative approaches can be designed, allowing the country's post-accident database to be restructured. It is argued that the sequence of activities performed by commercial airline operations, such as servicing the aircraft, refueling, and loading passengers and baggage, are dependent on human instincts aligned with the philosophy, policies, and procedures of the airline management. It necessitates additional research and analysis on human factors from the design of the aircraft through all other stages until it becomes the user's asset.

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